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RESEARCH MEMORANDUM

FLIGHT TESTS OF A MODEL HAVING SELF-SUPPORTING FUEL-CARRYING PANELS HINGED TO THE WING TIPS

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FLIGHT TESTS OF A MODEL HAVING SELF-SUPPORTING FUEL-CARRYING PANELS HINGED TO THE WING TIPS

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SUMMARY

An experimental investigation has been made in the Langley free-flight tunnel to determine the lateral stability and controllability of a model having self-supporting fuel-carrying panels hinged to the wing tips. These panels served to increase the effective wing area and span without introducing corresponding wing-bending moments. The investigation consisted of flight tests of the model to obtain a qualitative indication of the stability and control characteristics of the model with various hinge arrangements on the tip panels.

The results of the investigation showed that, with the tip panels hinged on a chordwise axis, erratic large-amplitude flapping of the tip panels caused the motions of the model to be jerky and difficult to control. When the hinge axis was skewed to produce aerodynamic restoring forces on the tip panels, which tended to keep the tips alined with the wing, the amplitude of the tip motions was reduced but was still excessive for skew angles as large as 45°. Linked flaps on the tip panels caused larger restoring forces than the skewed hinges, and a 20-percent-chord flap linked to move 3° per degree tip-panel rotation about the hinge almost entirely eliminated the motion of the panel relative to the wing. In this configuration, the flight behavior of the model was satisfactory.

INTRODUCTION

Air Force personnel have proposed that auxiliary fuel supplies be carried in lifting panels hinged to the wing tips of an airplane. The weight of the auxiliary fuel would be supported by these lifting surfaces so that there would be essentially no increase in wing loading and, because of the increased aspect ratio, the auxiliary fuel load probably could be carried more efficiently than by any other means. The purpose of hinging the tip panels to the wing was to avoid the wing bending loads which would otherwise be caused by the aerodynamic and mass forces

on the tips. This arrangement appeared very promising from the performance and loads standpoint, but the effect of the hinged-tip panels on dynamic-lateral stability and control could not be analyzed readily. In order to determine the effects of such a configuration on lateral stability and controllability, an experimental investigation has been conducted in the Langley free-flight tunnel on a flying model having hinged-tip panels weighted to represent a fuel load. The pilot's observations and graphical records were used to obtain a comparison of the flight behavior of the model with various configurations of hinged tips with that of the model without the tips and with the tips fixed rigidly to the wing.

APPARATUS AND TESTS

Plan-view sketches of the model are shown in figure 1 for the basic model without the tip panels and for the model with the tip panels attached rigidly to the wing. The various hinged-tip configurations covered in the tests are illustrated in figure 2. The basic model was a general research design with a wing having an aspect ratio of 5.06, taper ratio of 0.55, a Rhode St. Genese 35 airfoil section and conventional tail surfaces. The tip panels had the same airfoil section as the wing and, for the hinged-tip configurations, were hinged on an axis parallel to the lower surface. These panels were weighted to represent a full load equivalent to about one-third the weight of the basic model which is representative of present trends in wing-tip tank design. The size of the panels was such that the wing loading on them was about the same as that on the rest of the wing. Table I gives the mass characteristics of the basic model and of the basic model with the weighted tips rigidly attached. These characteristics were slightly different for the various hinged-tip configurations because of differences in installation details and because of small changes in the location of the weights for trim, but were about the same for the hinged-tip configurations as for the rigid-tip configuration.

The purpose of the skewed hinges and linked flaps was to minimize the flapping motion of the panels relative to the wing. Both of these devices cause aerodynamic forces on the tip panels which tend to keep them alined with the wing. Because the restoring forces are produced entirely by changes in lift on the tip panels, the forces required to aline the tip panel with the wing are not transmitted to the wing structure except for dynamic forces of short duration. In the first case, the hinge line was skewed so that as the tip panel rotated relative to the wing, the angle of attack of the tip panel varied so that restoring forces were produced. For example, as the tip panel rotated up, its angle of attack was reduced and the lift on the panel was reduced, tending to return it to its trim position. The second

device for obtaining restoring forces consisted of trailing-edge flaps on the tip panels linked to the wing so that the deflection of the flaps was proportional to the angle between the tip panel and the wing. For instance, as the tip panel rotated up, the flap went up and the lift on the tip surface was reduced, tending to return the panel to its trim position relative to the wing.

Flight tests of the model were made in the Langley free-flight tunnel (described in reference 1) for each of the configurations shown in figures 1 and 2. Two types of data were obtained in this investigation. Qualitative ratings of the flight behavior and control response were determined from the pilot's observations, and the motions of the model and of the tips were determined quantitatively from motion-picture records of the flights. All of the tests were made with the gap between the wing tips and the panels unsealed, except for the model with the plain tip panels with chordwise hinges which was flown with these gaps both sealed and unsealed to determine the effect of sealing this gap.

RESULTS AND DISCUSSION

The basic model and the model with the tip panels attached rigidly to the wing tips were used as bases for comparison for the model with the various hinged-tip arrangements. The flight behavior of the basic model was representative of that of a conventional airplane having very good stability and control characteristics. Both the controllability and general flight behavior of the model with the tip panels attached rigidly to the wing tips were less satisfactory than those of the basic model because of the slow response to aileron control and decreased lateral stability. When attached rigidly to the wing, the tip panels caused the rolling in response to aileron deflection to be slower than that of the basic model because they increased both the rolling moment of inertia and damping in roll of the model while the aileron rolling moments were about the same for both configurations. A lightly damped lateral oscillation was noted for the model with the tips whereas the oscillation was so heavily damped that it was not apparent in the flights of the basic model. This reduction in the stability of the lateral oscillation evidently resulted from the increase in rolling and yawing moments of inertia, an effect which is more fully discussed in reference 2.

In figure 3 the motions of the model and of the tips are compared for the five configurations having freely hinged tip panels. This figure shows the rolling motions of the model in controlled flight and the corresponding angles of bank of both of the tip panels. The conventional sign for the angle of bank was used for both the wing and the tip panels.

Figure 3(a) shows the motions of the model and the tip panels for the configuration with plain tip panels hinged on a chordwise axis. This flight record shows that there was considerable flapping of the tip panels with respect to the wing. These flapping motions were most noticeable after a gust or control disturbance when the motions of the tip panels were of relatively large amplitude. The flapping motion was not well damped and, because of its large initial amplitude, was noticeable for several cycles after a disturbance. The tip panels were relatively heavy (one-third the weight of the model without the panels) and jerked the model in bank so that its rolling motions were very erratic. This jerkiness of the rolling motions shows very clearly in the flight records of figure 3(a). The pilot of the model found the flapping of the tip panels very objectionable because of their effect on the rolling motions of the model. The frequency of the tip motions was too high to be controlled and it was difficult to distinguish between the natural rolling motions of the model and the transient motions caused by the action of the tip panels. However, the model rolled fairly rapidly in response to deflection of the ailerons and the controllability was satisfactory except for the jerkiness caused by the tip motions which were excited by the control disturbances. Sealing the gaps between the tip panels and the wing had no apparent effect on the behavior of the model except that it was observed to reduce the drag of the model.

Inasmuch as the flapping motions of the tips caused the flight behavior of the model to be unsatisfactory, the hinge lines were skewed in an attempt to reduce the tip flapping motions with respect to the wing. Although it is apparent from comparison of figures 3(b) and 3(c) with figure 3(a) that the amplitude of the tip motion was considerably less for the skewed-hinge configurations than for the chordwise-hinge configuration, it was considered excessive and the flight behavior was considered unsatisfactory. These results indicated that considerably larger aerodynamic restoring forces on the panels were required than those produced when the hinges were skewed 20° or 45°.

A linked flap on the trailing edge of the tip panels was tried since this device offered the possibility of obtaining very large aerodynamic restoring forces for small deflections of the tip panels. With the 14-percent-chord flap linked to deflect 2° for 1° deflection of the tip panel relative to the wing, the flapping was slightly less than that of the tip panel with the 45° skewed hinge, as shown by the comparison of figures 3(c) and 3(d). The flight behavior of the model, however, was not considered satisfactory in this configuration.

With the 20-percent-chord flap linked to deflect 3° per degree of rotation of the tip panel with respect to the wing, however, the flapping of the panels was very slight. For the flight record presented in figure 3(e), the pilot was intentionally disturbing the model to show

how closely the tip panels followed the banking motions of the wing. This flight record shows that the tip panels stayed very closely alined with the wing and that the little flapping which was present did not cause the pronounced jerkiness in the rolling motions of the model which characterized the motions for the other freely-hinged configurations. The flight behavior of the model in this configuration was considered satisfactory. In fact, the flight behavior was slightly better than when the tip panels were rigidly attached to the wings, probably because the model rolled faster in response to aileron control. The flight behavior, however, was not as good as that of the basic model without the tip panels.

Film records of the flight behavior of the model in the seven configurations discussed herein are available on loan from the NACA Headquarters, Washington, D. C. The results of this investigation are illustrated more graphically by the flight scenes of this motion picture than is possible in the present paper.

CONCLUSIONS

An experimental investigation was conducted in the Langley free-flight tunnel to determine the lateral stability and controllability of a model having various configurations of self-supporting fuel-carring panels hinged to the wing tips. The results of this investigation may be summarized as follows:

1. The model with the plain tip panels hinged on a chordwise axis was difficult to control because of erratic large-amplitude tip-panel motions which caused unsatisfactory flight behavior.

2. When the hinge axis was skewed to produce aerodynamic restoring forces on the tip panels tending to keep the tips alined with the wing, the amplitude of the tip motion was reduced. The restoring forces resulting from skew angles as high as 45° did not reduce the tip motions sufficiently and flight behavior of the model was unsatisfactory.

3. Linked flaps on the tip panels produced larger restoring forces than the skewed hinges and a 20-percent-chord flap linked to move 3° per degree tip-panel rotation about the hinge almost entirely eliminated the motion of the tip panel relative to the wing. In this configuration, the flight behavior of the model was satisfactory.

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REFERENCES

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2. Campbell, John P., and Seacord, Charles L., Jr.: The Effect of Mass Distribution on the Lateral Stability and Control Characteristics of an Airplane as Determined by Tests of a Model in the Free-Flight Tunnel. NACA Rep. 769, 1943.

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TABLE I

MASS CHARACTERISTICS OF MODEL

	Without hinged tip panels	Rigidly attached tip panels
Weight, lb	7.71	10.13
Wing loading, lb/ft^2	3.11	3.18
Radius of gyration about longitudinal body axis, spans . .	0.144	0.249
Radius of gyration about lateral body axis, spans	0.293	0.189
Radius of gyration about vertical body axis, spans	0.317	0.309

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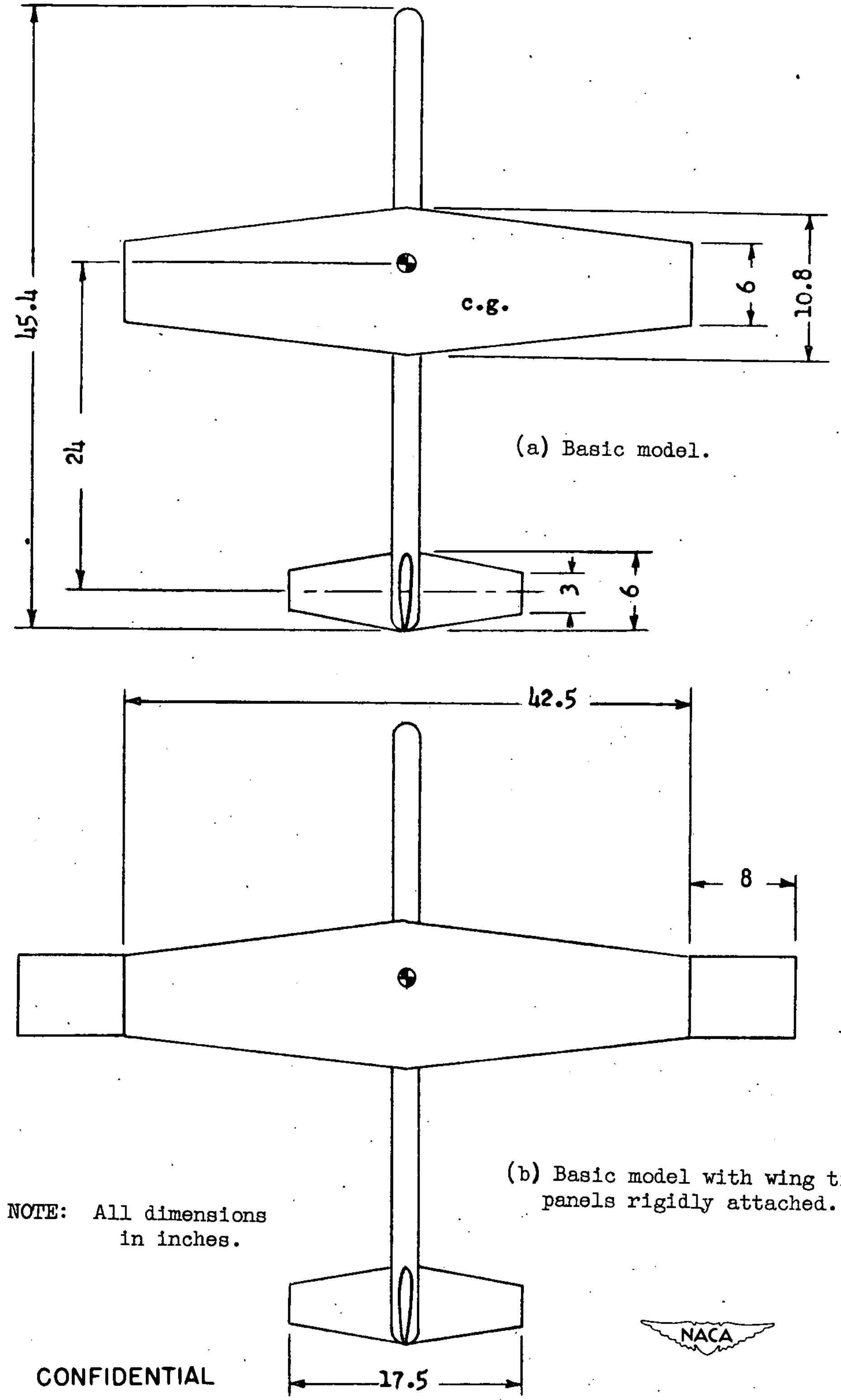

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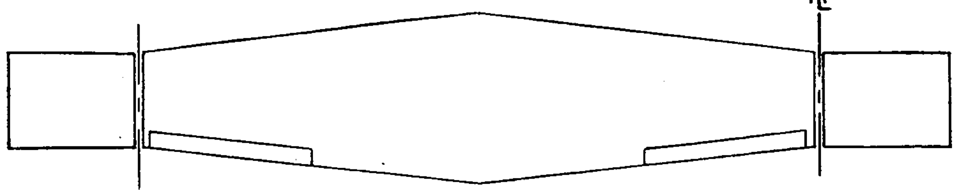
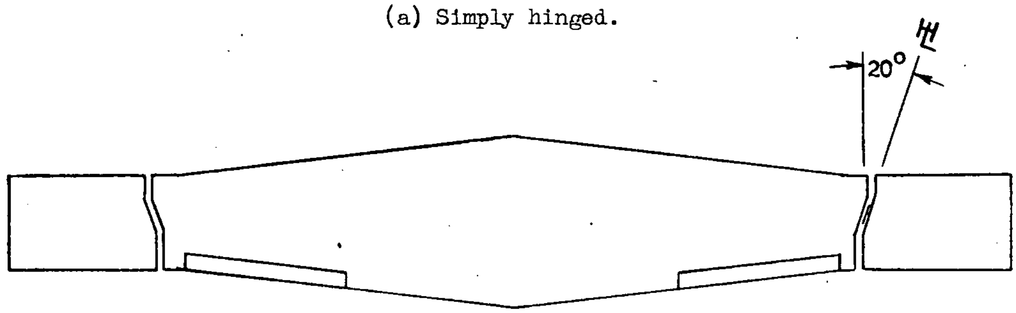
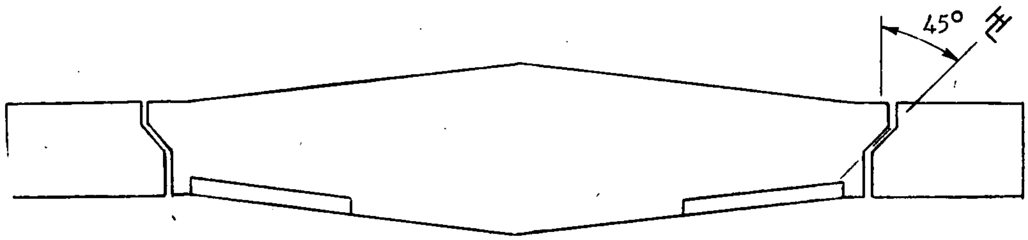
Figure 1.- Sketch of the model used in the tests with and without wing tip panels.



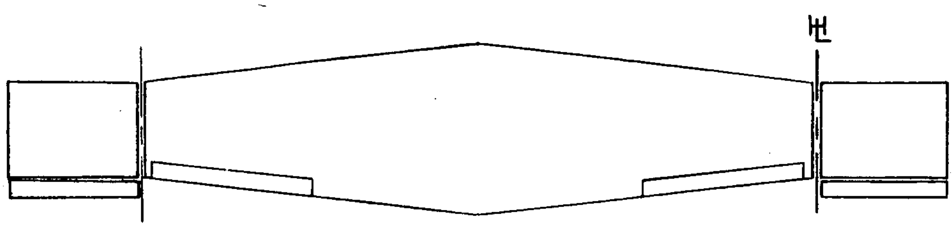
(a) Simply hinged.



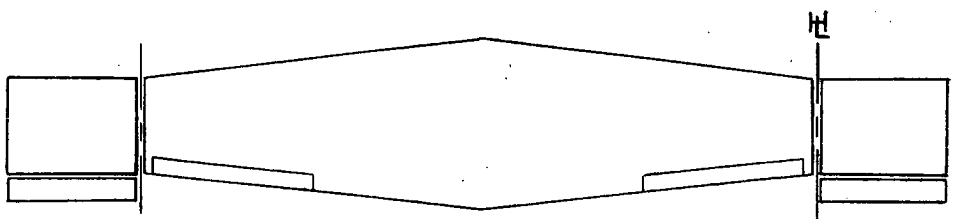
(b) 20° skewed hinge line.



(c) 45° skewed hinge line.



(d) 14 percent chord flap;
2:1 gearing ratio.



(e) 20 percent chord flap;
3:1 gearing ratio.

Figure 2.- Sketch of the hinged-wing tip-panel configurations tested.

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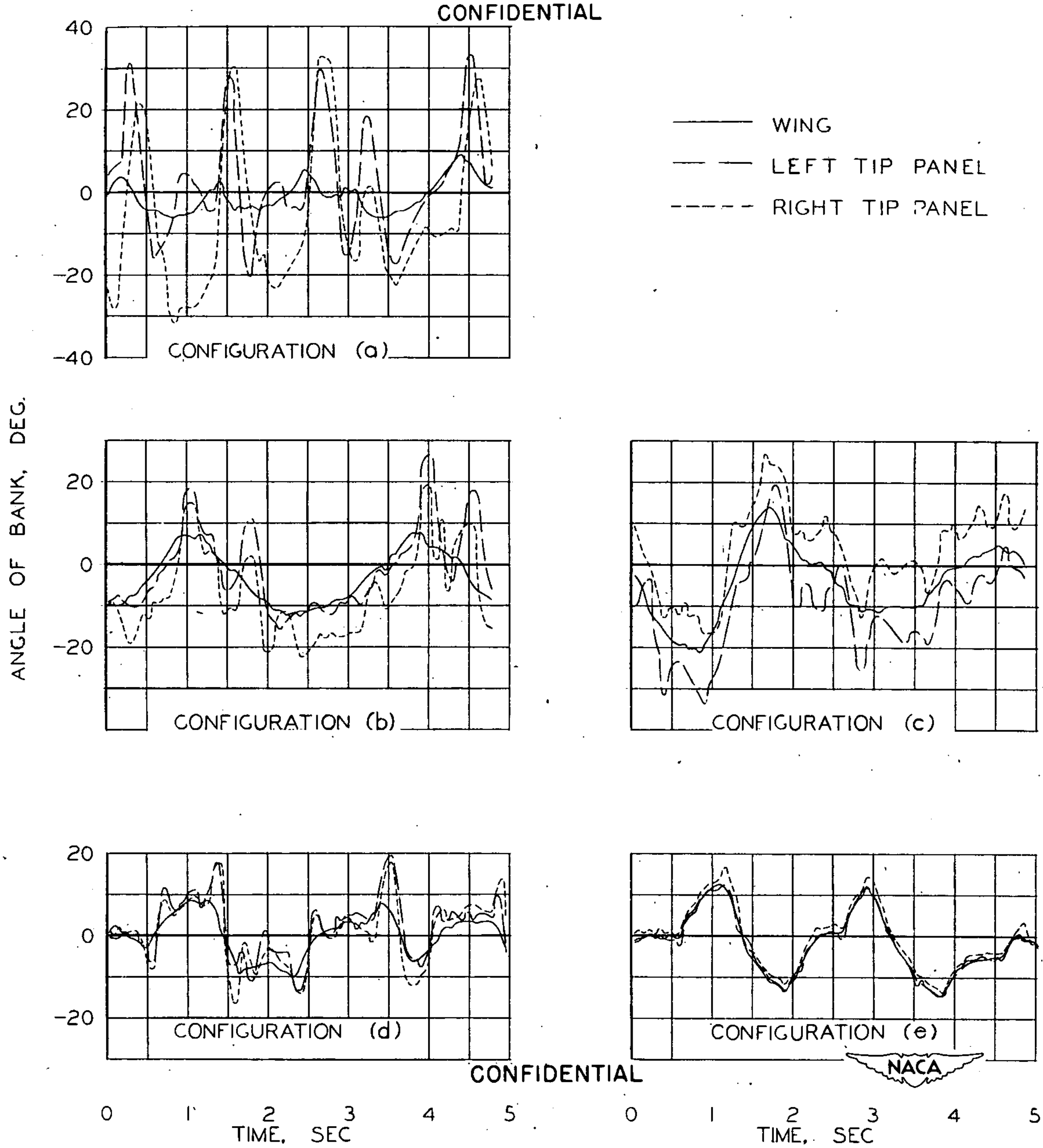

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Figure 3.- Comparison of the motions of the model and of the wing tips for the various hinge configurations corresponding to those of figure 2.